# Understanding Instructional Challenges and Approaches to Including Middle School Students with Disabilities in Makerspace activities: A cross-case analysis


Chung eun Lee
Vanderbilt University Medical Center
Nashville, TN, USA
chung.e.lee@vumc.org

Noah Samuel
University of Illinois at Urbana-Champaign
Champaign, IL, USA
nosamue2@illinois.edu

Maya Israel
University of Florida
Gainesville, FL, USA
misrael@coe.ufl.edu

Heather Arnett
University of Illinois at Urbana-Champaign
Champaign, IL, USA
hrb2@illinois.edu

Lisa Bievenue
University of Illinois at Urbana-Champaign
Champaign, IL, USA
bievenue@illinois.edu

Jeffrey Ginger
University of Illinois at Urbana-Champaign
Champaign, IL, USA
ginger@illinois.edu

Michele Perry
Perry and Associates
Austin, TX, USA
mperry@perryandassociates.net



## ABSTRACT

Given the proliferation of makerspace experiences in K-12 education, there is a growing need to ensure accessibility for all learners, including those with disabilities and those at risk of academic failure. The limited research on these populations suggests that it is essential to examine how a broader range of learners participate in K-12 maker activities and any barriers that they face. We employed a cross-case qualitative methodology to investigate issues of participation and engagement by collaborating with four teachers who incorporated maker activities into STEM or science classes in four different middle schools. Across the four schools, teachers reported multiple challenges faced by learners including student-specific, instructional, and systemic barriers. Despites these challenges, however, we found evidence of students with disabilities meaningfully participating in maker activities. Implications for future research and practices are discussed from an ecological model perspective.



## Keywords

Makerspace activities, K-12 education, engagement barriers, learning disabilities, inclusive makerspace


## 1. INTRODUCTION

### 1.1 Maker movement in K-12 Learning

K-12 formal education in the United States has a history of applied, hands-on learning in instructional areas such as inquiry-based science (Salmon, Rossman, & Dipinto, 2012), industrial arts (Barba, 2015), and art and design (Bequette, & Bequette, 2012), but maker activities as viable areas of instruction are only emerging in K-12 education (Meyer, 2017). The maker movement emerged in the early 2000s as informal learning environments emphasizing open exploration, collaboration, and failure as a source of iterative feedback (Peppler & Bender, 2013). In this article, making was characterized as hands-on exploration and learning that promotes relevance, tinkering, and iteration (Peppler, Halverson, & Kafai, 2016).

The idealized maker movement typically has focused on cultivating individual creativity rather than on aesthetics or specific tools or resources (May & Clapp 2017), which has sparked the attention of K-12 educators. K-12 leaders interested in bringing making into schools have focused on the "maker mindset," hoping to create opportunities that promote student empowerment and problem-solving (Meyer, 2017). Additionally, some educators suggested that making in K-12 can provide authentic learning experiences with emphasis on interest, identity, and learning-by-demand (Hsu, Baldwin, & Ching, 2017). These attributes – empowerment, problem-solving, and authentic learning – help to foster the 21st century skills of communication, collaboration, creativity, and critical thinking (Blackley, Rahmawati, Fitriani, Sheffield, & Koul, 2018; Peppler & Bender, 2013). Intentional educational makerspaces often aimed to "harness the same intellectual playground concept for the purpose of inspiring deeper learning through deeper questioning" (Kurti, Kurti, & Fleming, 2014, p. 8).

There is also the emerging need to understand how classroom implementation of making aligns with pedagogical theories of constructivism and constructionism, which are fundamental to the maker movement (Willett, 2017). These theories call for hands-on experiences driven by the learner and, as such, may conflict with some traditional structures of formal education (Willett, 2017). In many places, however, K-12 education is shifting toward more flexible implementations of standards and assessment that emphasize inquiry-based approaches to learning, which is more aligned with authentic, engaging, and personalized making (Meyer, 2017).



*FabLearn '20*, April 4–5, 2020, New York, NY, USA



ACM ISBN 978-1-4503-7543-6/20/04...$15.00
https://doi.org/10.1145/3386201.3386208

## 1.2 Barriers to Success for Students with Disabilities or At-risk in Maker Learning

Introducing making into K-12 education can enhance opportunities for students to engage in design and engineering practices (Martin, 2015). However, there are considerable barriers associated with maker learning in K-12 education. These barriers can extend beyond those present in the classroom to include additional structural (e.g., competing district-level priorities) and cultural/social (e.g., systemic exclusion of some students from certain classes) barriers. Structural barriers include accountability measures such as those arising from standardization that may not align with experiential learning, as well as access and availability of resources including teacher expertise. Halverson and Sheridan (2014) noted standardization as a structural barrier posing the greatest challenge to embracing the maker movement in K-12 education. Specifically, standardized testing and rigid curricula that must be followed by teachers results in less attention placed on experiential and constructivist approaches to learning. Other structural barriers to making in K-12 include access to tools and materials, professional development (PD), and limited staff with the knowledge and confidence to teach making (Halverson & Sheridan, 2014).

Similarly, Hira and colleagues (2014) discussed questions pertaining to the kind of learning that occurs through maker learning. Stakeholders may have legitimate concerns about maker activities regarding required time, alignment with existing curriculum, maker curriculum selection, influence on students' academic performance, and equity of resources between schools. In considering cultural barriers that may impact making, researchers noted that it is important to unpack who a maker is, the composition and importance of maker deliverables, and the kinds of access a maker has to tools (Barton & Tan, 2018). These social justice questions are associated with factors such as gender, race, ability, economic, and political conditions of makers. However, the popular narratives of who makers are and what they make often fail to address these equity-focused factors.

## 1.3 Students with Disabilities and other Struggling Learners in Makerspace Learning

It is important to consider how making experiences within the K-12 education system can be designed to be inclusive of all learners, including people with disabilities and those at risk (Barton & Tan, 2018; Seymour, 2018). Although there is a dearth of research exploring this phenomenon, previous research highlighted the success in maker learning among students with disabilities or at risk with appropriate support. For example, Seymour (2018) reported that students with disabilities and students who receive English as a Second Language (ESL) support presented positive outcomes in maker learning based on greater hands-on activities and present opportunities for collaborative learning. However, Klipper (2014) noted that students with disabilities were often missing in maker learning. There are numerous studies examining how teachers meet the needs of students with disabilities in core academic classrooms, but not in project-based maker activities.

Thus, it is essential to address critical gaps in the literature by understanding how teachers promote inclusive maker learning activities for students with disabilities and those at risk for academic failure. To better contextualize the context, an ecological framework was used to have a more holistic view of the maker activities in K-12 school systems, acknowledging the intertwined relationships between the student, teacher, and larger system (Bronfenbrenner, 1979). Under the ecological model, four levels are included: student (individual), teacher (microsystem – immediate connections to the student), school (mesosystem – interconnection between teachers and students), and state and national policies (macrosystem – cultural context of the student's life).

# 2. RESEARCH DESIGN

The purpose of this study was to gain an initial understanding of the pedagogical approaches of middle school teachers used to include both students with disabilities and those at risk for academic failure in maker learning activities. Specifically, two research questions (RQs) guided this study:

1. How are students with disabilities and students at risk for academic failure participating in middle school maker activities?

2. What barriers exist for students with disabilities and those at risk for academic failure in middle school maker activities?

As an exploratory study, we employed a cross-case qualitative approach (Stake, 2006) to understand the experiences of four general education teachers in meeting the needs of students with disabilities and students at- risk for academic failure in middle school maker learning activities. Each case was initially examined independently as a unique instrumental case study. Then, the cases were grouped into a multi-case analysis so they could be compared for similarities and differences.

## 2.1 Setting and Participants

Primary participants in this study were teachers recruited from two school districts in a mid-sized urban community in the Midwestern United States. Both school districts had a wide array of socioeconomic and cultural diversity and had policies in place to include students with disabilities in typical classroom settings. We observed several vulnerable populations: (1) students with disabilities, who were classified with individualized education plans (IEPs), (2) students at-risk, who were defined by enrollment in Tier 2 response-to-intervention programs, and (3) students receiving English as Second Language services. Within each District, U and X respectively, 18% and 12.6% of the students had individualized education programs or plans (IEPs), 15% of the students for both districts were in Tier 2, and 7.5% and 9.8% were receiving English as a Second Language (ESL) support. The theoretical model that we employed to develop our research instruments was built on identifying and supporting Universal Design Learning strategies, so while each of these populations has very different needs, they also all have some degree of common ground and can benefit from some of the same curricular and teaching opportunities.

### *2.1.1 Teacher at Summerfield*

Ms. Leslie taught science at Summerfield middle school in District U for over 20 years. In terms of STEM teaching experience, she coached the after-school STEM club for three years. Her science class was located in close proximity to other science teachers, whom she helped to mentor and collaborate with on a regular basis. In the observed 8th grade classroom, she had one student with a learning disability, one student with an emotional disorder, and four students who received ESL services.

### *2.1.2 Teacher at Westview*

Ms. Morgan taught for four years at Westview middle school in District X. Before her current position, she was a science teacher for eight years. She participated in varied PD activities throughout her career that ranged from nanoscience to more maker focused undertakings such as coding and Suminagashi. In her 8th grade classroom, she had one student with a learning disability, one student with a speech and language disorder, and one student who received ESL services.

#### *2.1.3 Teacher at Oakland*

Ms. Collins was a STEM teacher at Oakland middle school in District X. While this was her first year of teaching STEM at the middle school level, she brought twenty years of experience to the classroom that predominantly occurred in high school sciences. She actively sought PD in a diversity of content related applications (i.e., coding, the American Meteorological Society's Project Atmosphere). In her 8th grade classroom, she had one student with Autism Spectrum Disorder, two students with reading difficulties, three students with behavioral issues, and one student who is ESL.

#### *2.1.4 Teacher at Lincoln*

Mr. David was a first-year STEM teacher at Lincoln middle school in District X. He has limited PD exposure consisting mostly of classroom management. He had not received any STEM or makerspace PD prior to this study. In his 8th grade classroom, he had two students with ESL, and two students receiving Tier 2 support.

### 2.2 Data Collection

In the spring of 2018, each teacher in the study participated by implementing an 8 to 12-day instructional unit wherein they integrated makerspace activities in their STEM or science classrooms. Each teacher implemented different maker activities based on their STEM curriculum such as egg drop challenges, forensic file, and my dream home project. There was no specific PD or support for curriculum modification as this was exploratory study to understand current making practices in school. Two types of data were collected: classroom observations and teacher interviews.

#### *2.2.1 Classroom Observations*

Classroom observations were conducted across the entire maker learning units. The observation instrument was developed based on initial pilot testing and literature review. The instrument included codes for objectives, classroom atmosphere, instructional approaches taken by the teachers, barriers, and successes. This instrument also noted instructional approaches such as explicit instruction, accommodations, Universal Design for Learning (UDL), and behavior management. At least two observers were present during each observation, which typically lasted 40 to 60 minutes. In addition to the codes described above, each observer recorded field notes including: student and teacher movement, activities, dialogue occurring between teachers and students, and collaborations that occurred among the students both with and without disabilities. Lastly, observers collectively reflected on the lessons after each observation.

#### *2.2.2 Teacher Interviews*

To develop the semi-structured interview protocol, the research team began with a literature search (e.g., Hira et al., 2014; Seymour, 2018). Then, an initial interview protocol was developed by experts in the areas of maker learning and special education. The interview protocol was piloted with two middle school STEM teachers and the feedback was used to finalize the interview protocol. Questions were categorized into two sections: (a) students' use of metacognitive strategies during making activities, and (b) successes and failures of students with disabilities and those at risk for academic failure in making activities. Interviews took place after the instructional unit was completed. Each interview lasted from 30 to 50 minutes. Interviews were audio-recorded and transcribed by a graduate student.

### 2.3 Data Analysis

This study employed a comparative case study approach (Stake, 2006) with a constant comparative analysis (Glaser & Strauss, 1967) and emergent coding (Patton, 1999). Each teacher was initially treated as a separate case with respect to each data source. Data were initially analyzed by four researchers to operationalize definitions, clarify codes, highlight key words or phrases, and organize according to the research questions. The researchers discussed the codes until a consensus was reached, and an a priori codebook was developed with 13 codes (e.g., barriers, successes, instructional strategies, classroom atmosphere, student metacognition, activity type/materials). The codebook was frequently compared, combined, and revised considering content of each data source until a final version was developed. The final version of the codebook was then used to review and recode the data as needed. For data analyses, the software program DeDoose (2018) was used to code interview transcripts and observation field notes using the current version of the codebook. See Table 1 for examples from the codebook.

#### *2.3.1 Inter-rater Reliability*

Cohen's Kappa coefficient (Cohen, 1968) was computed to ensure the inter-rater reliability of the coding. After refining the codes, 20% of the data sources were coded by two members of the research team. Kappa scores ranged from -1 to +1 with scores of 0.61 to 0.8 indicating substantial agreement and scores above 0.81 indicating near perfect agreement (McHugh, 2012). Cohen's Kappa reliability was computed between the two researchers for Lincoln middle school at Kappa = 0.83 ($p < 0.001$), for Oakland middle school at Kappa = 0.78 ($p < 0.001$), for Westview middle school at Kappa = 0.84 ($p < 0.001$), and for Summerfield middle school at Kappa = 0.66 ($p < 0.001$).

**TABLE 1. Examples of Codes**

| Code | Description |
|---|---|
| Learned helplessness | When students face problems, students ask the teacher for help but do not try on their own. Lack of interest in activities or present challenging behaviors |
| Insufficient accommodation or instruction | Teachers provide insufficient accommodations for students with disabilities or at-risk. e.g., not using universal design for learning, explicit instruction, check-in, modeling, and/or prompting |
| Professional development | The need to participate in PD that focuses on both maker activities and/or effective instructional or class management strategies. |
| Technology failure | Internet disconnection or student log-in issues occur during the activities. Technology resources are easily broken. |

#### *2.3.2 Trustworthiness*

To enhance trustworthiness, researchers triangulated the findings using two data sources: observation notes and interview transcripts.

For example, both observation and interview confirmed the student engagement during hands-on activities, student collaboration, and support from teacher aide. Researchers also observed a few off-task behaviors during the classes while teachers reported challenging behavior or learned helplessness among students as one of the issues. Additionally, member checks were conducted with participants wherein themes emerging from the case study analysis were provided to the participants for feedback and clarification (Patton, 1999). This process resulted in only minor changes.

# 3. RESULTS

## 3.1 RQ1: Participation of Students with Disabilities in Maker activities

All teachers reported high engagement of students with disabilities in maker activities through hands-on experience, student collaboration, and support from paraeducators.

### *3.1.1 Hands-on Experience*

All four teachers reported that their students with disabilities and those receiving Tier 2 supports (additional instruction focused on specifically-targeted skills) were excited for the projects and were engaged with the maker activities. Teachers reported that the hands-on nature of maker activities facilitated engagement as these activities relied less on reading or math skills, compared to traditional instruction. When asked for the type of activities in which students at-risk were successful, Ms. Leslie reported that they performed well in activities such as labs, building, and designing (Interview, February 7, 2018). She mentioned that these learners were often reluctant to participate in activities that involved elaborate discussion of abstract academic concepts, especially open-ended discussion. Ms. Morgan similarly reported that she observed her students with disabilities performing particularly well during the hands-on maker activities. She gave the following example of a student with a learning disability who did a great job during a forensic file project:

> I love […] good success stories because it's like [the student saying], 'Hey, I got a reading disability and I'm still doing better than half the kids in this class who don't.

Observational data also supported the teachers' assertion that students with disabilities were engaged during the maker activities. For example, during an observation of Mr. David's class (May 11, 2018), one group of students who initially displayed off-task behaviors (e.g. moving, chasing one another into the seats, chatting) at the beginning of class became engaged when the hands-on activity started. During the egg drop challenge in Mr. David's class, students who were once making disruptive noise became involved with the project. The two students who received Tier 2 support were observed to be excited to create containers for the eggs that would then be dropped to see whether the egg would remain uncracked. These two students who were previously disengaged in the classroom suddenly became students to watch as they outperformed other students with their protective and strong container design.

Observations in Ms. Morgan's class were similar. During the design of an insect unit wherein students designed an insect and then printed the insect on a 3D printer (see Figure 1), the students were observed excited to participate in the process. Although they were sometimes off-task and needed extra support, they were motivated by the creation of their 3D design. Thus, in all observations, the students were motivated and became more engaged throughout the process, especially in developing and seeing the designs they created (i.e., container for the egg, 3D insect).

### *3.1.2 Student Collaboration*

Across different activities (e.g., designing roller coasters, a tiny home project, and egg drop challenges), we often observed student collaboration. For example, Ms. Collins, during a tiny home project activity, grouped the students so that they could help each other on troubleshooting processes. She explained: "I encourage them to look to their peers because I want them not to

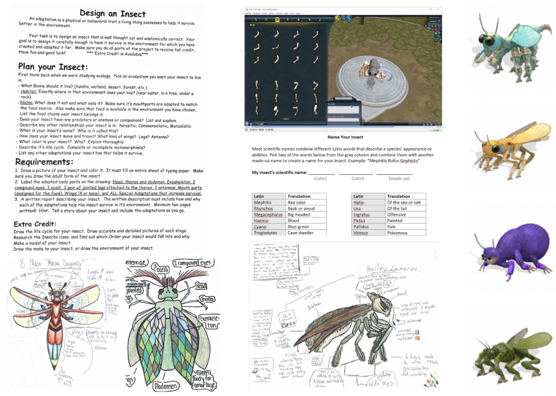

**Figure 1. Example of Instructional Activities**

just always rely on me. I try and encourage. It's called the three before calling [teacher]. Google it, think about it, and then ask a friend, and then ask the teacher" (February 14, 2018). Students frequently asked for help and affirmation from the teacher. Given the teacher-to-student ratio, Ms. Collins tried to ask students to collaborate or help each other if she was unavailable. Teachers reported and were observed using collaboration to engage the full range of learners in the making activities. For example, during an observation of Ms. Leslie's class (February 27, 2018), students were working on a heat transfer project. Ms. Leslie grouped three students together and explained the roles of each group member for each task. Assigning a role for a student with a learning disability promoted this student's participation and metacognitive thinking in the activity. On the field note, one observer wrote "students learn that others will help them to capture and decipher knowledge; they can work as a team on multiple levels."

### *3.1.3 Support From Paraeducators*

Lastly, three of the four teachers reported that having a paraeducator or instructional aides in their classroom led to positive outcomes for students with disabilities. Across observation and interview data, it was noted that the paraeducators provided extra support for students with disabilities by reminding students of the directions, prompting students when they needed verbal directions or support, modeling instruction, and answering questions. This additional support helped the students better navigate the maker activities. During an observation in Ms. Leslie's classroom (February 27, 2018), for example, a paraeducator showed a student with a learning disability how to graph the time points on the worksheets, a task that saved the teacher significant intervention time. Further, she walked around the classroom and provided individual prompts for any student who needed support, providing an additional set of eyes to help spot issues with and include students with disabilities as well as those at-risk.

Despite the support that the paraeducators provided, two of the teachers also described challenges. Both Ms. Collins and Ms. Morgan mentioned that paraeducators could only provide limited support due to beginner maker content knowledge or limited fluency in technology or materials used in activities. Teachers did not always have opportunities to meet with paraeducators in advance to inform them of anticipated curricular plans or student needs and paraeducators usually had few opportunities for professional development or technology training. As a result, technology failures or curricular challenges could still hamper an entire classroom, even with the additional help.

However, it is critical to note that paraeducators still made a major difference to students with disabilities or who are at risk for academic failure, who otherwise may abandon making activities when the teacher is unable to help. The perhaps larger issue is the overall lack of paraeducators in general, as they were absent entirely in many classrooms with students with learning disabilities and even when present not at a one to one ratio.

## 3.2 RQ2: Barriers to Engaging in Maker Activities

Across data categories, we categorized them into three sections: (1) students, (2) teachers, and (3) current practices in school.

### *3.2.1 Student*

All teachers experienced performance avoidance and limited persistence among the students with disabilities as well as those receiving Tier 2 support in the making activities. The students rarely tried these activities on their own. Ms. Leslie explained that her struggling learners, especially those with disabilities, often exhibited learned helplessness, wherein they would not initiate or persist in learning activities independently. Mr. David, similarly, stated that students with disabilities feared failure in his class and exhibited limited persistence. The students' fear of failure often meant that he had to work one-on-one with them to help them maintain effort and persistence. Ms. Collins reported similar lack of persistence and explained that she prompted her students and gave directions, but continued to set the expectation for the students to complete tasks as independently as possible. Classroom observations also showcased task avoidance. The students with disabilities were often observed exhibiting off-task behaviors (i.e., making noise, using phone, chasing one another) as compared to their peers who were also talking with their peers, but were doing so while also working on their projects. Teachers usually attempted to re-engage the students by verbally or physically intervening to redirect them. However, given the teacher and student ratio, it is challenging for teachers to re-engage all the students.

### *3.2.2 Teacher*

The classroom observation shows that it was too challenging for teachers to implement instructional strategies (e.g., explicit instruction, modeling, prompting) to meet the needs of students with disabilities or at-risk in maker activities. Ms. Collins prepared directions for every class including the agenda on the smartboard, worksheets, and verbal directions. However, she was not seen providing any form of cues to the students to look at those directions, which often resulted in students asking the same question repeatedly. Similarly, during Ms. Collins' dream home project (February 28, 2018), field note reflections indicated

> Lots of further instruction is needed to perform merger (instruction seemed to have been given too quickly for students to grasp the necessary steps). Most interactions appear to be depositing of information to the student instead of prompting techniques to determine how to figure out the answer.

Classroom observations also indicated limited implementation of instructional strategies to support students with disabilities. Ms. Morgan, for example, had a student with a learning disability whose IEP accommodations included reduced reading load and additional time to complete assignments. Despite these mandated accommodations, observers noted that the teacher has not given any relevant accommodations or instructions. Observers reported

> It seems like everyone receives the same format of worksheets. Also, it is not clear whether a student with a learning disability understands the directions. It might be better to provide both oral and written directions for her. She seemed [she was] just sitting in the chair, and not doing any work until the teacher check-ins with her (February 10, 2018).

### *3.2.3 Current practices in School*

#### *3.2.3.1 Limited Access to STEM for Students with LD*

The number of students with disabilities was fewer than expected in all four classes observed. Although some students with disabilities were included, there were no students with intellectual disabilities, behavior disorders, or other more moderate to severe disabilities. Except for the science class in District U, the three schools ran on an 8-week, quarter-based schedule for STEM Lab and other non-core classes. These non-core classes included band/orchestra, foreign language, drama, and STEM Lab classes. Mr. David noted that most students with intellectual and developmental disabilities were "pulled out" of the STEM course to receive reading instruction (or other specialized interventions) and did not have an opportunity to participate in the STEM class.

Thus, although there were a few students with disabilities in the STEM classes, the teachers did not have many experiences teaching students with disabilities in their classrooms. Mr. David said, "we actually don't get students with disabilities in our class for STEM. [...] They will do arts, or they'll do drama, or they'll do music" (May 16, 2018). Indeed, researchers have only observed a few ESL students or students with learning or behavior issues in his classroom. There were no students with intellectual or developmental disabilities in Mr. David's class. Ms. Collins had an opposite experience in which she had more struggling learners in her class because most high-achieving students enrolled in courses such as foreign language or band. She reported that, "[A]s you've seen, we have some behavioral issue kids that are in there...I get one or two that are higher level and then most of them are not. They're the ones who are struggling." However, her class also did not include students with more significant needs.

#### *3.2.3.2 Technology Failure*

Across observations and interviews, teachers experienced technology challenges during maker activities. These challenges fell into four categories: (1) Technology failure, (2) lengthy boot-up time, (3) internet stability issues, and (4) challenges associated with logging into systems such as Google classroom. For example, Ms. Morgan has a 3D printer in her classroom but the 3D printer did not always work reliably. Furthermore, some schools have used Chromebooks or PCs that have some internet connection issues and students constantly struggle to log-in, often mistyping or forgetting their login or password. As instructional time was limited (classes are only 40 minutes long), the technology challenges were viewed by teachers as problematic for implementation of the making activities.

#### *3.2.3.3 Limited Professional Development*

Three teachers from District X mentioned that there were limited opportunities for PD on either maker activities or inclusive instructional strategies. All four teachers were interested in learning different kinds of hands-on maker activities, but at the time of this study, they had not had opportunities to participate in any maker-related PD. During the interviews, researchers asked the teachers about their background and any PD that they received. Mr. David reported, “No. There were no maker related activities or even things like STEM-based [professional development]” (May 16, 2018). Two teachers confided that they struggled executing new maker activities. Ms. Morgan reported that PD was not always presented in ways that teachers could easily apply new content into their classrooms. Similar to PD on maker activities, teachers did not report having opportunities to attend PD related to culturally responsive instructional strategies or inclusive instructional strategies.

#### *3.2.3.4 Limited Instructional Time*

Across four schools, a project usually took a week and each session lasted approximately 40 minutes. Setting up and wrapping up activities often took at least 10 minutes which left only 30 minutes for the activities themselves. Due to this limited time, there was not always time for student exploration and iteration. Ms. Morgan, for example, reported difficulty in facilitating tinkering due to time constraints. Furthermore, researchers observed that learners who needed additional support only received this instruction when they asked for one-on-one help as teachers dealt with 20 or more students per class. For instance, Mr. David explained that he was trying to provide accommodations for students with disabilities, but it took a lot of time to revise materials and instructions. He said, “I think a lot of teachers will say they can’t do [accommodations for students with disabilities] because they just don’t have time and that’s unfortunate” (May 16, 2018).

## 4. DISCUSSION

This study investigated how students with disabilities and those at-risk for academic failure participate in maker activities, with a focus on understanding barriers that may limit their participation. The current findings were discussed based on the ecological framework, see Figure 2. There were four main findings.

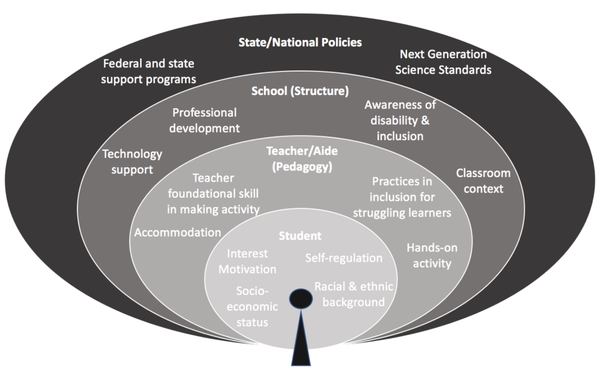


**Figure 2. The ecological conceptual framework for the study**

First, as shown in the model, an important part of this study centered on understanding the individual student within school-based maker activities. These individual-level variables emerged as potentially influencing the performance of students within the maker environment and included their level of interest in these activities, self-regulation skills, socioeconomic status, disability status, and ethnic background. From this study, teachers reported that the interest and engagement of the students improved as they participated in hands-on activities. This is consistent with Seymour’s (2018) finding that students with disabilities or at-risk performed better during hands-on maker activities. However, while the hands-on nature of an activity may positively impact academic success, degree of self-regulation - how students followed instructions given by the teachers, their focus on tasks, and other general conduct within the maker activity - such as performance avoidance and limited persistence, could negatively influence task performance.

Second, it was critical to provide students with disabilities or at risk with appropriate accommodations. Although our findings indicated that hands-on activities and more project-based opened the door for students with disabilities or at risk to new interactions, needs and opportunities, they may need more explicit instruction to participate in makerspace activities. For example, students with disabilities or at risk often exhibited learned helplessness (Causton-Theoharis, 2009), which impedes creativity and independent thought during hands-on projects. Finding the right level of support requires teachers to balance the amount of intervention or guidance that facilitates self-learning without discouraging learners. Research on makerspace related curriculum and teacher interactions can help illuminate how to provide that balance between explicit instruction and open exploration while also encouraging students to use metacognitive strategies. For example, the development of mediated choices, scaffolding to promote persistence or goal-setting, and outlets for personal expression are cited as benefits of maker learning (Peppler & Bender, 2013), and these should be further explored with students with disabilities.

Third, teachers across all schools reported limited support from administrators to develop inclusive, STEM-supporting maker activities, which resulted in less confidence to teach new maker lessons. Thus, administration must seek to support initiatives that support teachers’ pursuits for a more inclusive and robust learning environment. To promote better classroom makerspace activities, future PD should be developed including foundational understanding of both traditional project-based making activities (i.e., ideation, hands-on tinkering, documented iteration, reverse engineering, remixing and situated deliverables), as well as appropriate pedagogical approaches within these activities, such as inquiry-based learning or peer-to-peer instruction and reflection. Equally as important, teachers need to be provided the conditions that allow them to develop and test new skills and curriculum. Smaller class sizes, longer class periods and support from aides or graders all are potential ways to enable this, though perspectives and identities are arguably more important in enabling successful implementations (Campos et al., 2019, Tan, 2018).

Lastly, the macrosystem addresses how issues emerging from the school district, state, and federal policies impact the classroom. One such issue was the limited support for resources for hands-on STEM-based programs and its lack of representation in standardized measures of accountability. For example, in interviews, all teachers from STEM classrooms (which are considered to be non-core academic classes) reported limited support from the administration to run the maker activities. On the other hand, the science teacher (a core subject) reported having adequate resources in her classroom. Schools’ commitment to providing adequate instructional resources is important for students and their parents in making decisions about subject enrollment (Hira et al., 2014). These issues can only be solved by district or state policies that would bring maker learning to the fore as an important part of a child’s learning experience.

While this study revealed significant student interest in making activities, a major finding was that there was a low representation of students with disabilities in classrooms that provided maker opportunities. This limitation may be due to structural issues specific to school systems. For example, in District X, many students with disabilities received special education support, such as reading recovery, instead of being enrolled in the STEM class alongside their peers. However, given the emerging research on student engagement, future research and advocacy efforts should focus on increasing access to maker activities for people with disabilities (Brady, Salas, Nuriddin, Rodgers, & Subramaniam, 2014; Klipper, 2014).

## 4.1 Limitations

This study should be interpreted in light of several limitations. First, this exploratory study only examined the experiences of four teachers in public schools in a single city in the USA, which has implications for generalizability. Thus, there is an enormous opportunity for replication and comparison across settings with a larger sample of teachers and students with disabilities. Second, the results reviewed here only described the teachers' perspectives alongside observations of students. The next stage of the study explored experiences and input from students with disabilities more directly through interviews, screen capture and artifact analysis but at the time of publication analysis of this data was not yet complete.

## 4.2 Implications for Research and Practice

Findings from this study have several implications for future research and practice. First, students with disabilities or those at-risk for academic failure were often given fewer opportunities to engage in maker activities as compared to their peers. Given that "maker pedagogies can benefit students with diverse learning needs" (Hughes, Fridman, & Robb, 2018, p. 395) and "function as a bridge between creativity and curricular content for students who struggle in traditional classrooms" (p. 394), it is imperative to advocate for inclusion. Furthermore, it is possible to better ensure maker activities themselves specifically capitalize on the unique assets and perspectives these students bring to the classroom.

Second, just as there is potential for the "maker mindset" to empower students, teachers can also be empowered. Cross (2018) indicated 40% of makerspace teachers reported that they had received no PD on makerspaces at all; it is therefore imperative to move towards a model of PD for teachers that not only addresses making practices but that also supports cognition, engagement, and accessibility (Oliver, 2016a). This begins with providing space and time for participation in maker activities as a learner in order to build a foundation in the elements critical to making while gaining confidence in implementing these hands-on activities in an inclusive manner. This approach is further supported through instilling teaching practices such as alternative entry points for accessing the making activities, modeling the use of tools, materials, problem solving strategies, scaffolded learning, and personal relevance that benefit not only those with disabilities but all learners (Kafai et al., 2014). Furthermore, teachers would benefit from continued exposure and experiences with making by means of coaching and participation in a community of practice.

Third, research suggests that there are significant opportunities for students with disabilities to develop metacognitive skills by engaging in making activities. For example, students with disabilities often present with learned helplessness (Causton-Theoharis, 2009), which impedes creativity and independent thought during hands-on projects. Finding the right level of support requires teachers to balance the amount of support that facilitates self-learning while not discouraging students. Research on maker activities can help illuminate how to provide that balance between explicit instruction and open exploration while also encouraging students to use metacognitive strategies. For example, the development of choice, persistence, goal-setting, and personal expression are cited as benefits of maker learning (Peppler & Bender, 2013), and these should be further explored with students with disabilities.

Further, as the data reviewed here is only based on teacher interviews and classroom observations, it is important to understand students' voices with regard to participation in making activities. To examine their perspectives, surveys or interviews with those students with disabilities should be used to consider their interests and gain further understanding about their learning. This type of research could lead to making activities that may be more accessible for those populations.

# 5. CONCLUSION

This study illustrates how teachers perceive participation of students with disabilities and those at risk for academic failure in middle school maker activities, as well as barriers they faced in developing and implementing inclusive maker activities. While these barriers can seem daunting, the study also suggests that there are opportunities to support teachers in overcoming these barriers through district level systems of support. As the study suggests, for example, contextualized PD will be necessary to help teachers meet the needs of all their learners in maker activities. Through continued investigation into intervention-based maker studies, we can begin to understand how to reach the broadest range of students so that they can have more meaningful participation in these STEM-driven maker activities.

# ACKNOWLEDGMENTS

This work was supported by the National Science Foundation under Grant DRL #1721236. The views expressed are those of the authors and do not necessarily represent the views of the National Science Foundation.

# REFERENCES

[1] Archer, A. L., & Hughes, C. A. (2010). *Explicit instruction: Effective and efficient teaching.* Guilford Press.

[2] Barba, E. (2015). Cultural change in the twenty-first century shop class. *Design Issues, 31*(4), 79-90.

[3] Barton, A. C., & Tan, E. (2018). A longitudinal study of equity-oriented STEM-rich making among youth from historically marginalized communities. *American Educational Research Journal, 55,* 761-800.

[4] Basham, J. D., & Marino, M. T. (2013). Understanding STEM education and supporting students through universal design for learning. *Teaching Exceptional Children, 45*(4), 8-15.

[5] Bequette, J.W., & Bequette, M.B. (2012). A place for art and design education in the STEM conversation. *Art Education, 65*(2), 40-47.

[6] Blackley, S., Rahmawati, Y., Fitriani, E., Sheffield, R., & Koul, R. (2018). Using a "makerspace" approach to engage indonesian primary students with STEM. *Issues in Educational Research, 28*(1), 18-42.

[7] Bowler, L., & Champagne, R. (2016). Mindful makers: Question prompts to help guide young peoples' critical technical practices in maker spaces in libraries, museums, and community-based youth organizations. *Library & Information Science Research, 38,* 117-124.

[8] Brady, T., Salas, C., Nuriddin, A., Rodgers, W., & Subramaniam, M. (2014). MakeAbility: Creating accessible makerspace events in a public library. *Public Library Quarterly, 33*(4), 330–347.

[9] Bronfenbrenner, U. (1979). *The ecology of human development.* Cambridge, MA: Harvard University Press.

[10] Campos, F., Soster, T., & Blikstein, P. (2019). "Sorry, I was in teacher mode today": Pivotal tensions and contradictory discourses in real-world implementations of school makerspaces. *FabLearn 2019*, March 9-10, NY, USA.

[11] Causton-Theoharis, J. N. (2009). The golden rule of providing support in inclusive classrooms: Support others as you would wish to be supported. *Teaching Exceptional Children, 42*(2), 36-43.

[12] Cohen, J. (1968). Weighted kappa: Nominal scale agreement with provision for scaled disagreement or partial credit. *Psychological Bulletin, 70*(4), 213–220.

[13] Cross, A. (2018). *Makerspace educators need professional development, too*. EdTech Focus on K-12 https://edtechmagazine.com/k12/article/2018/08/makerspace-educators-need-professional-development-too

[14] Evertson, C. M. (1994). Classroom rules and routines. In T. Husen & T. N. Postlethwaite (Eds.), *International encyclopedia of education: Research and studies* (Vol. 2, 2nd ed., pp.816-820). Oxford, UK: Pergamon.

[15] Glaser, B. G., & Strauss, A. L. (1967). Grounded theory: The discovery of grounded theory. *The Journal of the British Sociological Society, 12*, 27–49.

[16] Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review, 84*(4), 495–504.

[17] Hira, A., Joslyn, C. H., & Hynes, M. M. (2014). Classroom makerspaces: Identifying the opportunities and challenges. In *2014 IEEE Frontiers in Education Conference (FIE) Proceedings* (pp. 1–5).

[18] Hsu, Y., Baldwin, S., & Ching, Y. (2017). Learning through making and maker education. *Techtrends, 61*(6), 589-594.

[19] Hughes, J., Fridman, L. & Robb, J. (2018). Exploring maker cultures and pedagogies to bridge the gaps for students with special needs. In G. Croddock, C. Doran, & L. McNutt (Eds.), *Transforming our world through design, diversity, and education* (393-400).

[20] Israel, M., Pearson, J., Tapia, T., Wherfel, Q., & Reese, G. (2015). Supporting all learners in school-wide computational thinking: A cross case analysis. *Computers & Education, 82,* 263-279.

[21] Jones, W. M., Smith, S., & Cohen, J. (2017). Preservice teachers' beliefs about using maker activities in formal K-12 educational settings: A multi-institutional study. *Journal of Research on Technology in Education, 49,* 134-148.

[22] Kafai, Y., Lee, E., Searle, K., Fields, D., Kaplan, E., & Lui, D. (2014). A crafts-oriented approach to computing in high school: Introducing computational concepts, practices, and perspectives with electronic textiles. *ACM Transactions on Computing Education*, *14*(1), 1-20.

[23] Klipper, B. (2014). Making makerspaces work for everyone. *Children & Libraries: The Journal of the Association for Library Service to Children, 12*(3), 5-6.

[24] Kurti, R. A., Kurti, D.A., & Fleming, L.I. (2014). The philosophy of educational makerspaces. *Teacher Librarian, 41*(5), 8-11.

[25] Mastropieri, M. A., & Scruggs, T. E. (1994). Text versus hands-on science curriculum: Implications for students with disabilities. *Remedial and Special Education, 15*(2), 72-85.

[26] Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research, 5*(1), Article 4.

[27] Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom.* Constructing modern knowledge press Torrance, CA.

[28] May, S., & Clapp, E.P. (2017). Considering the role of the arts and aesthetics within maker-centered learning. *Studies In Art Education, 58*(4), 335-350.

[29] McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia Medica, 22*(3), 276-282.

[30] Meyer, L. I. (2017). Planning and implementing a makerspace in your school. *T H E Journal, 44*(3), 26-28.

[31] Moon, N. W., Todd, R. L., Morton, D. L., & Ivey, E. (2012). Accommodating students with disabilities in science, technology, engineering, and mathematics (STEM). Atlanta, GA: Center for Assistive Technology and Environmental Access, Georgia Institute of Technology.

[32] Oliver, K. M. (2016). Professional development considerations for makerspace leaders, part one: Addressing "what?" and "why?" *TechTrends, 60*(2), 160–166.

[33] Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research, 34*(2), 1189-1208.

[34] Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Kappan, 95*(3), 22-27.

[35] Peppler, K., Halverson, E. R., Kafai, Y. B. (2016) Makeology: Makes as learners (Volume 2), New York, NY: Rouledge.

[36] Salmon, D., Rossman, A., & Dipinto, V. (2012). Knowing by doing and doing by knowing. *Science Scope, 35*(6), 70-74.

[37] Seymour, G. (2018). The inclusive makerspace: Working with english language learners and special education students. In H. Moorefield-Lang (Ed.), *School library makerspaces in action.* Santa Barbara: CA.

[38] Stake, R. E. (2006). *Multiple case study analysis*. New York: The Guildford Press.

[39] Tan, M. (2018). When makerspaces meet school: Negotiating tensions. *Journal of Science Education and Technology, 28,* 75-89.

[40] Willett, R. (2017). Learning through making in public libraries: theories, practice, and tensions. *Learning Media and Technology, 43,* 250-262.